



Do we minimize costs and emissions by optimizing energy generation?

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Type of activity

This exercise is a problem of operations research, suitable for exploring optimization techniques and decision-making processes related to SDG 7, "Affordable and Clean Energy."

Target educational level

It can be addressed to last courses of High School students and to any university student.



Problem statement

The energy demand of a region is 800 MW. To meet this demand, solar, wind and hydro power can be generated. The solar power generation capacity is 500MW, the wind power generation capacity is 300MW and the hydro power generation capacity is 400MW. The cost of generating electricity per MW is 100000€ for solar, 150000€ for wind and 200000€ for hydro. The CO2 emissions per MW generated from solar power are 0.02 kg, 0.01 kg for wind power and 0.005 kg for hydro power. The maximum CO2 emission is 11.5 kg.



In addition, to promote efficiency in the use of natural resources, it is necessary to ensure that the sum of solar and wind power generation capacity is equal to or greater than hydroelectric capacity.

Tasks:

Determine the optimal allocation of solar, wind, and hydroelectric generation capacities to minimize the generation cost while satisfying all constraints.

Solution

The problem is formulated as an optimization model.

Decision variables:

x_{solar} : solar capacity used

x_{wind} : wind capacity used

x_{hydro} : hydroelectric capacity used

Objective function:

$$\min 100000x_{solar} + 150000x_{wind} + 200000x_{hydr}$$

Constraints:

1. Solar constraint: $x_{solar} \leq 500$
2. Wind constraint: $x_{wind} \leq 300$
3. Hydro constraint: $x_{hydro} \leq 400$
4. Total capacity constraint: $x_{solar} + x_{wind} + x_{hydr} \geq 800$
5. CO2 emissions constraint: $0.02x_{solar} + 0.01x_{wind} + 0.005x_{hydro} \leq 11.5$
6. Energy efficiency constraint: $x_{solar} + x_{wind} \geq x_{hydr}$

A program in R that solves the above problem might be:

```
library(lpSolve)

# Problem parameters
demand <- 800 # Energy demand in MW
solar_capacity <- 500 # Solar generation capacity in MW
wind_capacity <- 300 # Wind generation capacity in MW
hydro_capacity <- 400 # Hydroelectric generation capacity in MW

solar_cost <- 100000 # Cost of solar generation per MW
wind_cost <- 150000 # Cost of wind generation per MW
hydro_cost <- 200000 # Cost of hydroelectric generation per MW

solar_emissions <- 0.02 # CO2 emissions per MW generated from solar energy (kg)
wind_emissions <- 0.01 # CO2 emissions per MW generated from wind energy (kg)
hydro_emissions <- 0.005 # CO2 emissions per MW generated from hydroelectric
energy (kg)

emission_limit <- 11.5 # CO2 emissions limit (kg)
constraints <- matrix(
  c(1, 0, 0, # Solar Constraint
    0, 1, 0, # Wind Constraint
    0, 0, 1, # Hydro Constraint
    1, 1, 1, # Total capacity Constraint
    solar_emissions, wind_emissions, hydro_emissions, # CO2 emissions Constraint
    1, 1, -1), # Energy efficiency Constraint
  nrow = 6, byrow = TRUE
)

# Create the optimization model
model <- lp("min",
  objective.in = c(solar_cost, wind_cost, hydro_cost),
  const.mat = constraints,
  const.dir = c("<=", "<=", "<=", ">=", "<=", ">="),
  const.rhs = c(solar_capacity, wind_capacity, hydro_capacity, demand
    , emission_limit, 0)
)

# Print the model's status
print("Model Status:")
print(model$status)

# Capacity used for each energy source
utilized_solar_capacity <- model$solution[1]
utilized_wind_capacity <- model$solution[2]
utilized_hydro_capacity <- model$solution[3]

print(paste("Utilized Solar Capacity (MW):", utilized_solar_capacity))
print(paste("Utilized Wind Capacity (MW):", utilized_wind_capacity))
print(paste("Utilized Hydroelectric Capacity (MW):", utilized_hydro_capacity))
```

The results would be:

Utilized Solar Capacity (MW): 400

Utilized Wind Capacity (MW): 300



Utilized Hydroelectric Capacity (MW): 100